Growth and Asexual Reproduction of the Starfish *Nepanthia belcheri* (Perrier)

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ABSTRACT: *Nepanthia belcheri* (Perrier) attains a longest arm radius of 11 mm during the first growing period, 18 mm in the second, 23 mm in the third, and 27 mm in the fourth year. At radii of approximately 15 mm and 22 mm, asexual reproduction by fission can occur. Fission takes place during the active growth period of the year. The resulting individuals develop new arms resulting in a typical adult arm number of six or seven. The regenerating arms grow more rapidly than the old arms and cannot be differentiated at longest arm radii of 27 mm and 32 mm.

ASEXUAL REPRODUCTION by fission or autotomy has been noted for several species of asteroids. These reports have been summarized and reviewed by Hyman (1955) and Swan (1966).

Clark (1938), writing on *Nepanthia belcheri* (Perrier) 1876, stated, "It is a literal truth that no two of the 56 specimens at hand, nearly all from Lord Howe Island, are exactly alike in number, size and form of arms"; and Edmondson (1935), commenting on *Nepanthia* sp. from Hawaii noted, "Few symmetrical specimens are found, nearly all having rays of unequal size. The number of rays varies, seven usually being present in the more symmetrical individuals."

N. belcheri has been recorded along the Pacific coast of Australia from Low Isles (16°S) to Port Jackson (33°S) (Clark, 1946; Endean, 1953, 1956, 1961).

METHODS AND RESULTS

The starfish used in this study were collected at Dunwich (27°31'S, 154°24'E) in Moreton Bay, Queensland, during the period 1952 to 1955. Water temperatures in Moreton Bay vary from a mean summer maximum of 27.5°C to a mean winter minimum of 14.5°C (Endean, Kenny, and Stephenson, 1956).

The specimens were collected, by hand, from oyster lease areas, on mud flats, at approximately low water mark of neap tides. In all, 27 collections, totalling 827 animals, were made at various times, including all months of the year except January. The variability of form, which is typical of the species, is shown in Figure 1.

The radii of all arms of each starfish were measured and the number of arms noted. The records of radius of the longest arm were arranged in 1-mm class intervals, expressed as percentages, and plotted as a series of monthly histograms (Fig. 2). From these histograms, modes of frequency distribution of radius of longest arm were extracted, using the methods outlined by Cassie (1954), and a growth curve was drawn (Fig. 3). The February, March, and April collections were considered too small to be treated in this manner, but these data have been included in other analyses.

These results show that *Nepanthia* increases in radius from August to January but that there is little growth in the February-to-July period. During the first active growing period the starfish attain a radius of approximately 11 mm; during the second growth period they increase from 11 to 18 mm, in the third from 18 to 23 mm, and in the fourth from 23 to 27 mm. The small number of measurements available for individuals of radius greater than 27 mm does not warrant detailed analysis.

Extrapolation from this growth curve suggests that metamorphosis takes place in August and that the life span of the species is four or more years.

Table 1 shows the monthly incidence of indi-

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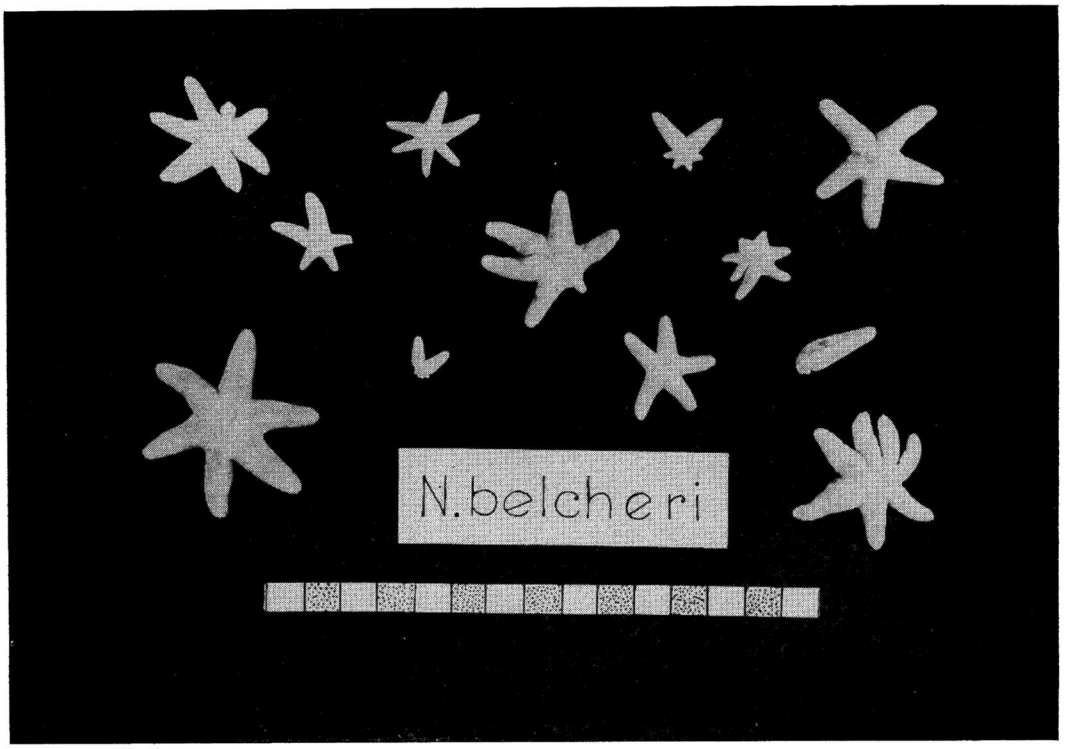

FIG. 1. Selected specimens of *Nepanthia belcheri,* showing the variability of form; scale in centimeters.

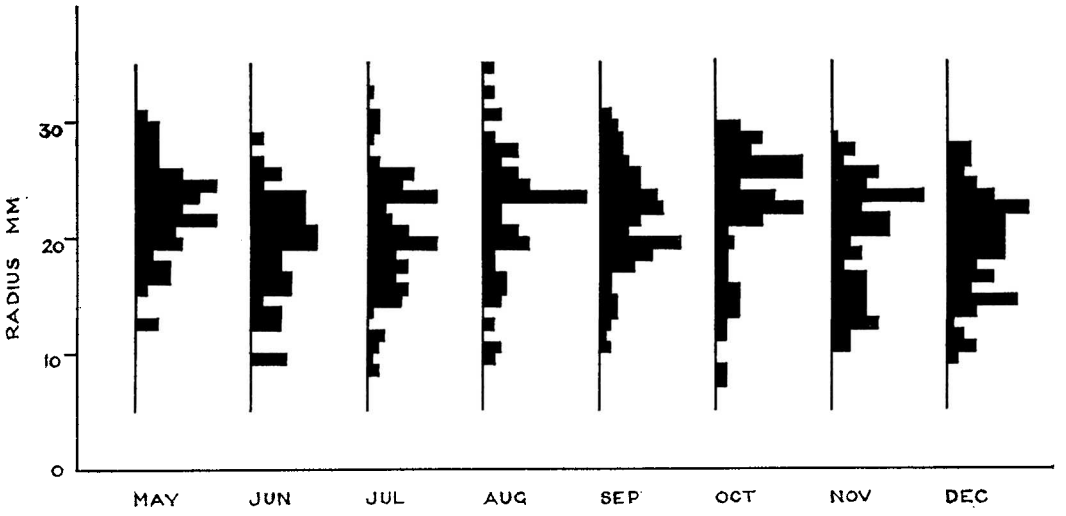

FIG. 2. Frequency distribution histograms of longest arm radius (in millimeters) of *Nepanthia belcheri.*

viduals with different numbers of arms, and Table 2 shows the relationship between the number of long and short arms in starfish showing marked variability in arm length. A 5-mm difference between long and short arms was taken as the minimum difference to be noted.

In the population studied, 80 per cent of the individuals had six or seven arms, and 41 per

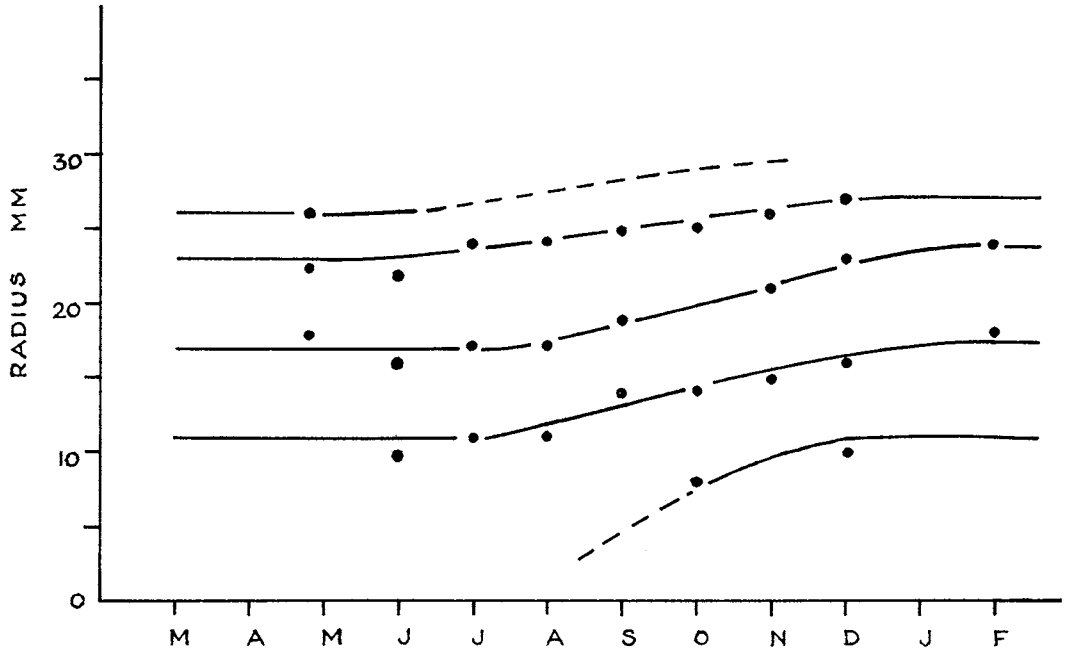

FIG. 3. Growth curve for *Nepanthia belcheri.*

TABLE 1

MONTHLY INCIDENCE OF *Nepanthia belcheri* WITH VARIOUS ARM NUMBERS

	NUMBER OF ARMS							
MONTH	1	2	3	4	5	6	7	8
Feb.			1		2	7	2	
March					3	5	2	
Apr.		1			1	12	1	
May			1		2	31	18	1
June					8	26	8	1
July		1	1	4	6	49	31	4
Aug.					4	17	9	
Sept.	1	10	5	4	16	114	47	
Oct.	1	12	9	2	5	78	41	1
Nov.	2	16	8	3	9	57	29	2
Dec.	2	3	1		12	62	24	1
No. of individuals	6	43	26	13	68	458	213	10
Percentage of population	0.6	5.3	2.9	1.4	7.0	54.8	25.5	1.2

cent showed some evidence of fission, either in the form of new breaks or of marked differences in arm radius. All starfish with fewer than five arms showed evidence of recent fission, and individuals with two or three arms were more common than those with one or four. The patterns of splitting and regrowth that occur most commonly are those which give a total arm number of six. The incidence of animals with fewer than five arms is greater in the months September to December than at other times of the year.

The radii of the longest arms of those starfish showing evidence of recent fission were drawn

TABLE 2

RELATIONSHIP BETWEEN NUMBERS OF LONG AND SHORT ARMS OF *Nepanthia belcheri*

NUMBER OF SHORT ARMS	NUMBER OF LONG ARMS					
	1	2	3	4	5	6
1		1	1	4	14	1
2		1	3	17	5	
3		18	26	7		
4	5	61	23			
5	8	38	2			
6	2	1				

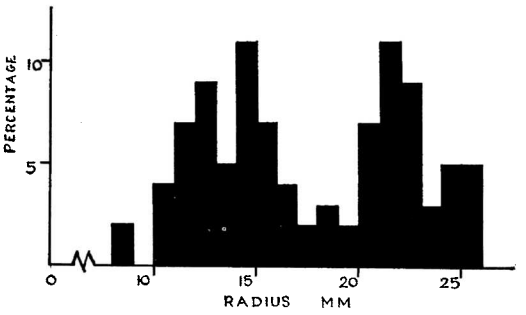

FIG. 4. Frequency distribution histogram of longest arm radius (in millimeters) of *Nepanthia belcheri* specimens showing evidence of recent fission.

as a percentage histogram (Fig. 4), resulting in a bimodal distribution with modes at 15 and 22 mm radius.

Table 3 lists measurements from starfish showing regeneration, arranged to show the difference in radius between the longest arm and the new arms. Only differences of more than 5 mm, have been included. It is clear from these data that the regenerating arms grow more rapidly than the longer arms and that the difference in arm length from one individual reaches a minimum at sizes of 27 and 32 mm radius. During the period of time when the longest arm has increased from 15 mm to 27 mm radius the regrowing arms have grown to a radius of at least 22 mm (allowing 5 mm as normal variability). Following fission of larger animals, the regenerating arms develop to a minimum radius of 26 mm while the long arm increases from 22 mm to 32 mm radius.

TABLE 3

INCIDENCE OF ARM LENGTH VARIATION IN *Nepanthia belcheri*

RADIUS OF LONGEST ARM	VARIATION IN ARM LENGTH WITHIN INDIVIDUAL																	
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
9	1																	
10	1		2		1													
11			2	1	1													
12	1	1				1	1											
13	1	3	1	2	1	1												
14		3	2		3	3		1										
15	4	3		3	7	1	1	1	1	2								
16	1	1	1	2	2	3	1	1		2								
17	3	3	1	1	1	2	2	1	1	1	1	2						
18	4		1	3	1	1	1		2	1	2	2	3					
19	2	1	3	1	1		1	2	1	1	2	2						
20	7	2	4	3	4	4	3	1	2									
21	6	2	2	1			2	1	1									
22		2	5	2	1		2	2	2					2	1	1	1	
23	3	3	1	4				1			1							1
24	1		3	3		1												
25	4	1	4	1	3						1							
26	2	1	2	1				1			1	1					1	
27	1	1						2	1	2								
28						2	1											
29				1	2		1			1								
30				1	1													
31	2	1	1															
32		1																

DISCUSSION

From the results described above, a typical pattern of growth and asexual reproduction can be stated for *N. belcheri*. Metamorphosis occurs during the winter months, probably in August, and growth is rapid during the spring months but ceases in January. During the growing period of either the second or third year, at an arm radius of approximately 15 or 22 mm, the starfish may reproduce asexually by splitting. Each of the resulting two individuals develops new arms, making a total arm number of six or seven. The new arms grow more rapidly than the old ones and after the second growing period cannot be differentiated by size. The life span of the species is at least four years.

Interspecific comparisons of growth rates of asteroids are difficult to make due to differences in species size and measurement methods employed by different authors. These difficulties are overcome, however, by expressing the annual increase in size as a percentage. The growth rate of *Nepanthia* decreases with age, being 64 per cent in the second year, 28 per cent in the third year and 17 per cent in the fourth. Similar treatment of data available for other species shows that *Asterias vulgaris* increases in size 71 per cent in the second year (Smith, 1940), *Crossaster papposus* grows 125 per cent during one year (Milligan, quoted by Hyman, 1955), and *Pisaster ochraceus,* 190 per cent during one year (Quayle, quoted by Swan, 1966).

Crozier (1920) reported that fission occurred in *Coscinasterias tenuispina,* at Bermuda, at all times of the year except January and February, which is the breeding season, while Swan (1966) commented that *Coscinasterias acutispina,* from Japan, is a species in which fission occurs at any time of the year. In *Nepanthia,* splitting is more common during the active growth period (September to December) than at other times of the year.

Sclerasterias and *Coscinasterias acutispina* are listed by Swan (1966) as starfish in which fission occurs only in juveniles, whereas *Nepanthia belcheri* splits during either the second or third year. Edmondson (1935), discussing Hawaiian starfish, does not mention growth rate or size and season of fission for *Nepanthia* sp.

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